Lambda-Conversion using remote fully automated WebLab

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***Abstract* — A web-lab wavelength converter setup is presented, offering optical services to other laboratories in the Fapesp-KyaTera Optical Network. In addition, optical generation, amplification and filtering, at several gigabits per second, is also available. An Optical Spectrum Analyzer controlled through the Internet provides accurate analyses of filtering, amplification and wavelength conversion.**

***Index Terms*—Optical Communications, Filtering, Wavelength Conversion, Optical Amplification**

I. Introduction

The Kyatera project is an experimental optical fiber network linking several laboratories around Campinas, Brazil, creating a shared workspace for universities and the research community. The web-lab concept offer the possibility of accessing the resources of many laboratories through a high speed optical network, without requiring to be present in front of the equipments [1].

In particular, the wavelength conversion in an optical network is the alteration of the original carrier wavelength of an optical signal in order to make possible the transmission of a bit stream from one node to another when the original wavelength is being used by other channel [2]. In its simplest way implemented here, the cross gain modulation (XGM) of a Semiconductor Optical Amplifier (SOA) is used to achieve the wavelength conversion [3 - 5].

This work presents a setup that offers optical wavelength conversion services to other laboratories connected to the Fapesp-KyaTera and MCT-CPqD-GIGA Optical Networks. The customer can use the amplification, wavelength conversion, and filtering of his optical signal or to generate another modulated signal in a desired wavelength. The setup can verify the effects of filtering, amplification and wavelength conversion at the frequency domain with the Optical Spectrum Analyzer receiving the optical signal.

II. The WebLab Setup

The setup is presented in Fig. 1 and its most important components are described:

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1- Tunable Laser: generates a wavelength selected by the remote operator from 1525nm to 1565nm (optical C-band). The wavelength of the laser light will be the wavelength of the converted signal at the output of the SOA (Semiconductor Optical Amplifier).

2- PRBS Generator: generates a pseudo - random bit sequences of electrical square signals as a bit stream at a rate up to 13 Gbit/s to stimulate the Mach-Zender Type Optical Modulator in order to create an appropriate modulation pattern in the CW laser light generated by the tunable laser. In addition, the pulse shape can be modified by the remote operator, using the facilities of the remote operation through the internet.

3.SW1 2x2 Voltage Controlled Optical Switch: can switch two optical paths. This process permits the CW laser light (from the tunable laser) to pass towards the optical switch SW2 or cross the inputs and outputs of the CW laser light from the tunable laser into the Mach-Zehnder Lithium Niobate Amplitude Optical Modulator, in order to create an appropriate optical modulation pattern in this signal.

4.SW2 2x2 Voltage Controlled Optical Switch: can switch two optical paths and permits the laser light from the optical switch SW1 to reach the optical switch SW3 and/or lets the laser light from the KyaTera's fiber to reach the photo-diode in order to implement an optical power meter. The other possible optical switch operation lets the laser light from the optical switch SW1 to reach the photo-diode and lets the laser light from the KyaTera's fiber reach the optical switch SW3.

5. Photo-Diode 1 Data Acquisition: converts the laser light into electrical signals, supplying an optical power data. The laser can be originated in the KyaTera network, in the tunable laser, resulting in a CW signal or, in the Mach-Zender Type Optical Modulator, resulting in a modulated signal.

6. SW3 – 1x2 Voltage Controlled Optical Switch: can switch two optical paths letting the laser light from the optical switch SW2 reach either the optical fiber reel, that consists in a optical time delay, or the conversion type SOA, that will change that original signal wavelength.

7. SOA Current Controller: allows the remote operator to control the electrical current that flows through the SOA in order to modify the wavelength conversion process dynamics and to meet the optical amplification and wavelength conversion operator's requests.

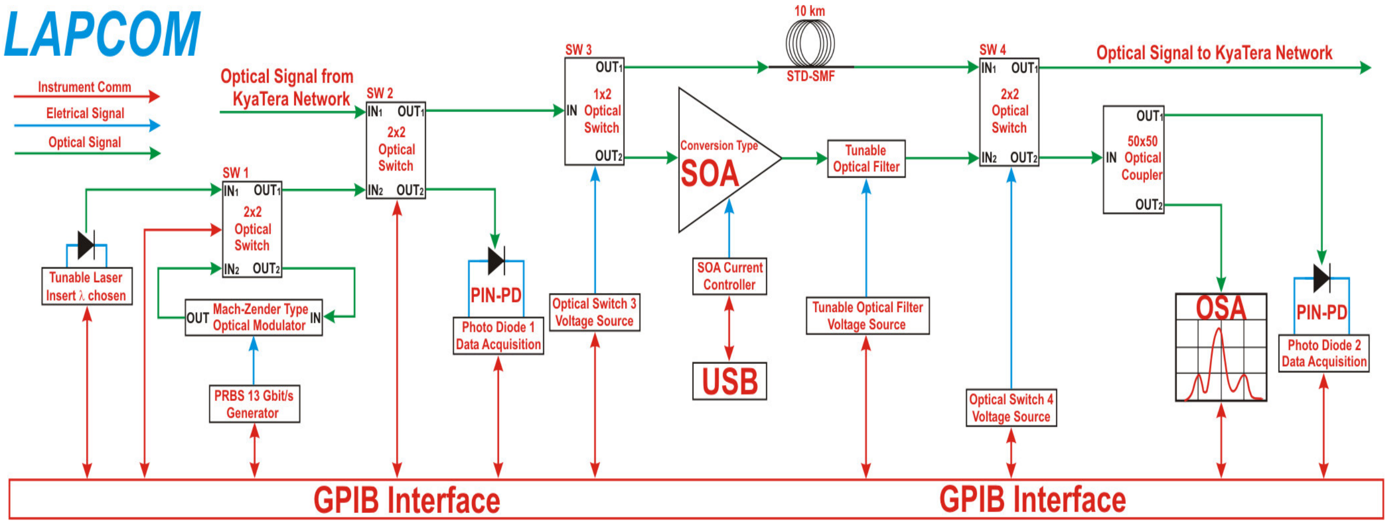

Fig. 1 – Wavelength converter weblab experimental setup

8. Tunable Optical Filter: it's a tunable band pass optical filter that has a wavelength window that can be shifted in wavelength, or to be tuned, in order to allow the signal portion centered in the center filter's wavelength to pass.

9. SW4 – 2x2 Voltage Controlled Optical Switch: can switch two optical paths. The first path lets the laser light from the optical fiber reel to reach the optical coupler and lets the laser light from the tunable optical filter to reach the way to go out (into KyaTera network). The second path allows the laser light from the optical fiber reel to reach the way to go out to KyaTera network and lets the laser light from the tunable optical filter to reach the optical coupler.

10. Optical Spectrum Analyzer: acquires and displays the optical spectrum features of the laser light either from the optical fiber reel or from the tunable optical filter according to the optical switch SW4 operation mode. The remote operator can request any parameter as if he was in front of the instrument, for example, start and stop frequencies. The remote operator also can request the trace points to retrace in his favorite mathematical software.

11. Photo-Diode 2 Data Acquisition: it will be used jointly with the tunable optical laser to determine the wavelength of the optical spectrum trace peak point. When the remote user to call this resource, he will know the wavelength value of the optical spectrum's current signal.

III - The Weblab Software Interface

The web lab concept aims to share instrument resources among several research groups. As an example, it includes the use of a very expensive research instruments thousand miles away without buying them, through a partnership between research groups connected to the KyaTera high speed network or connected to the internet.

The Fig.1 is the web lab user interface, where the user can point over the optical circuit component symbols and click it for pop-up a small window. The window has LabView buttons allowing the remote user to control all instruments in the setup, such as to either alter a voltage over the tunable optical filter in order to tune the central wavelength or to act on the SOA Current Controller to change the electrical current value in order to meet some features requested in the wavelength conversion process.

An important device to be controlled is the optical tunable filter, since the desired converted wavelength must be set with the tunable laser and with the tunable optical filter of Fig 1. The tunable laser (used as the pump optical signal in the wavelength converter) has embedded commercial software capable to choose the desired wavelength with an error of 30 GHz on the optical frequency. To setup the optical tunable filter (*JDS Uniphase model VCF050*), the step motor is controlled by a USB driver with a program (using C++ software) developed here to permit fine control of the tunable filter position. The user interface is shown in Fig. 2, where the target wavelength is set by the distant user, and after pressing the *start* button, the current wavelength is being displayed with the desired time interval. The driver, the microprocessor, and the power supply were implemented with circuit board techniques. Also, a AD converter was necessary to make the correspondence between the analog filter position (given by a potentiometer) and the digital control signals.

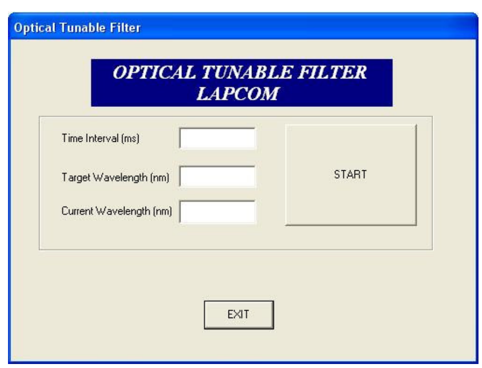

Fig. 2 – User interface to control the optical tunable filter.

The remote user can have an optical communications tutorial explaining from the basic to the advanced level, allowing him to transmit large packets of information over the Optical Fiber network..

IV – Experimental Results

The wavelength converter of Fig. 1 is based on the cross-gain modulation process since a broad-range transparent optical wavelength converter is a key device giving flexibility to the wavelength division multiplex (WDM) systems at the interconnection nodes and by the allocation of the network control to the sub-networks managers [4, 5]. The wavelength converter was implemented under the MCT-CPqD-GIGA Optical Network project. To enable the WGM wavelength conversion, the SOA was mounted in a box with an independent power supply where the ideal bias current is previously adjusted, as shown in Fig. 3.

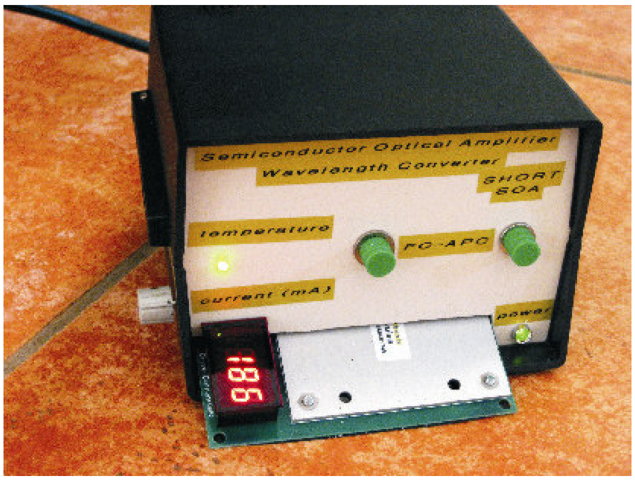

Fig. 3 – The SOA XGM wavelength converter setup box.

A typical eye diagram of a converted signal is shown in Fig. 4 for an optical signal modulated at 7 Gbps in the return to zero (RZ) format. A clear eye can be noted besides the optical noise at the upper part of the bit stream. The noise is caused by the amplified spontaneous noise (ASE) that is inherent to the SOA.

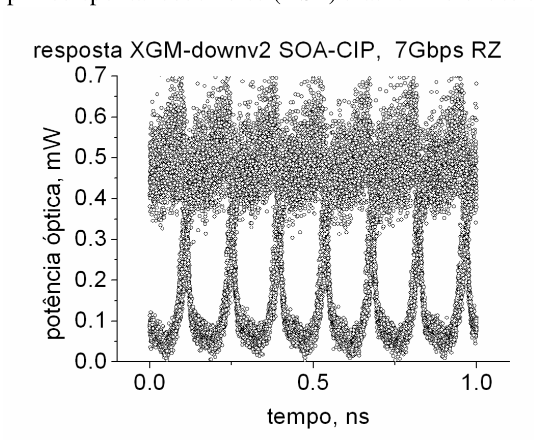

Fig. 4 – A typical eye diagram of the converted signal.

The overall efficiency of the conversion process can be analyzed with the Q factor of the eye diagram. The results are presented in Fig. 5 for the down converted NRZ (non return to zero) signal in the SOA-XGM process, where the input signal Q factor is represented by the doted line and the converted signal by the continuous line. As expected, the converted signal is always inferior in quality than the input signal and the quality decreases with the bit rate. However, a Q of 5 might be acceptable for fiber to the home optical networks systems.

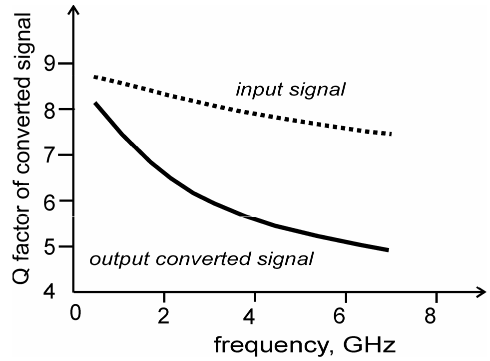

Fig. 5 – Overall quality of the NRZ down converted signal measured with the XGM-SOA wavelength converter

V – Conclusion

A wavelength converter web lab setup was presented using the cross gain modulation process using a commercial semiconductor optical amplifier, and internet controlled tunable filter, pump laser, and optical switches.

In addition, optical generation, amplification, and filtering at several gigabits per second is also possible. An Optical Spectrum Analyzer controlled via Internet provides accurate analyses of filtering, amplification, and wavelength conversion at the frequency domain.

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